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REPORT

Permissible bass rise in talks studios

No. 1970/10

Research Department, Engineering Division
THE BRITISH BROADCASTING CORPORATION

RESEARCH DEPARTMENT

PERMISSIBLE BASS RISE IN TALKS STUDIOS

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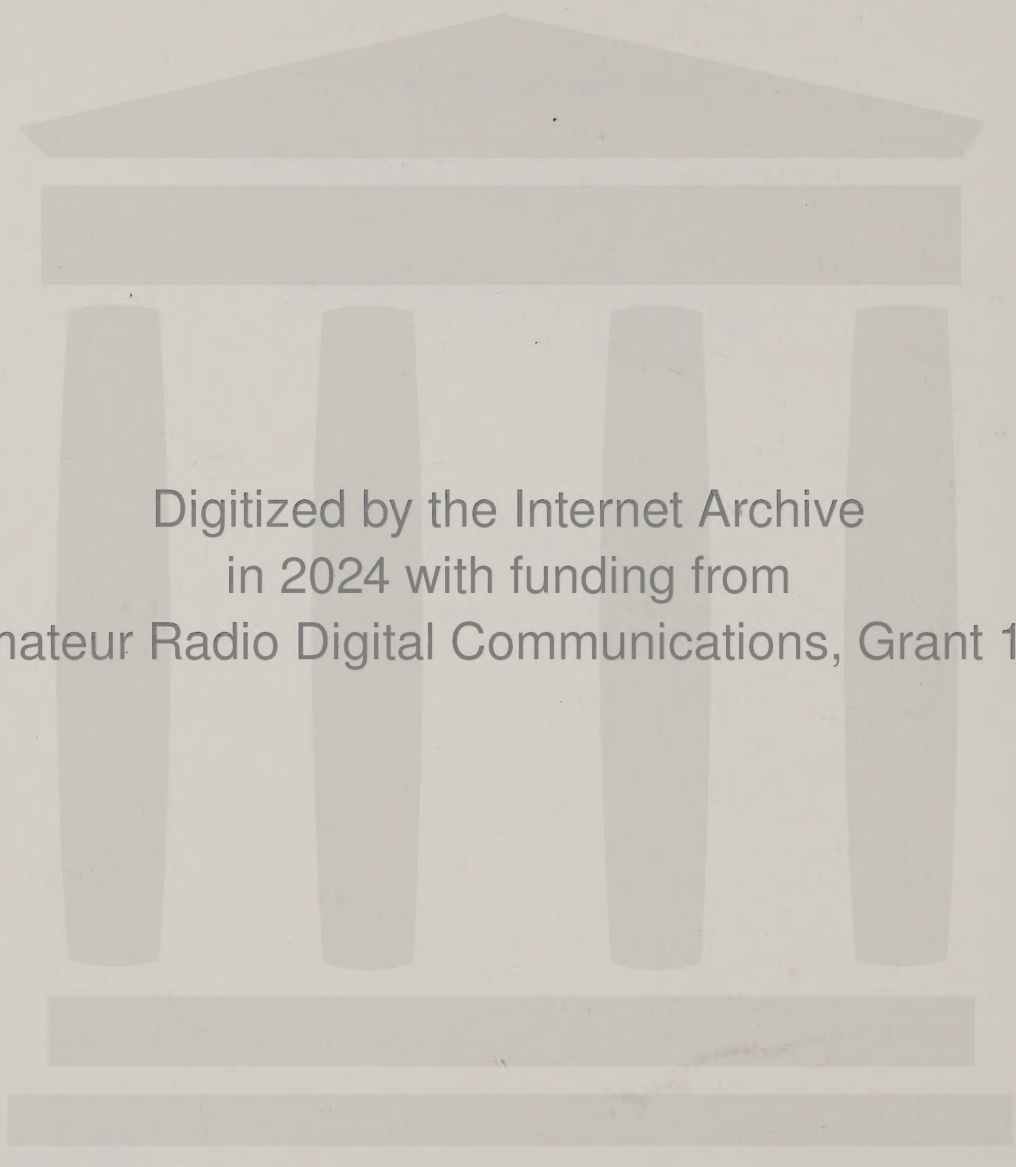

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PERMISSIBLE BASS RISE IN TALKS STUDIOS

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PERMISSIBLE BASS RISE IN TALKS STUDIOS

SUMMARY

An investigation has been carried out into the extent to which the low-frequency reverberation-time may be allowed to rise in a talks studio without impairing speech quality. Factors likely to affect the acceptability are taken into account. It is shown that microphone type has a particularly strong influence on the acceptability. Recommendations for allowing a degree of bass rise are made which permit a reverberation time of 0·73s at 63 Hz.

1. INTRODUCTION

This report is concerned with the specification of acceptable reverberation-time/frequency characteristics for talks and discussion studios, at low frequencies.

In the past, the BBC has recommended that the reverberation-time of a talks studio should be independent of frequency.[1] At frequencies above about 200 Hz this aim is fairly easily accomplished because of the validity of the simplifying assumptions on which reverberation-time formulae are based. In any case, if there is a design error it is fairly easily corrected by removal or addition of relatively cheap absorbents.

At low frequencies, the situation is quite different. The wavelengths involved are comparable with, or considerably greater than, the dimensions of a talks studio, and so the assumptions on which the reverberation-time formulae are based break down.* Bass absorbers are expensive to make and install, bulky and difficult to add to or remove from an existing installation, and do not always behave as expected.

In earlier attempts to establish reverberation-time/frequency criteria for small studios the results were indefinite. The investigations were based on subjective assessments of operational studios but these appeared to be confused by non-acoustical differences between studios. For example, there was evidence of a significant correlation between the comfort and appearance of a studio, and the assessment of it. However, experience with certain recently constructed studios again led to speculation that reverberation-time at low frequencies could be allowed to rise without undue adverse effects.

For the present investigation use was made of an experimental studio whose acoustical characteristics can be altered easily by the addition or removal of modular absorbers of various types from the walls and ceiling; the modules are 1·22 m x 0·61 m. The studio has the internal dimensions 6·7 m x 4·9 m x 3·4 m which are about the same as those of a large talks or discussion studio.

2. SCOPE OF EXPERIMENTS

The general method of conducting the investigation was to record speech under various conditions in the experimental studio and to ask listeners to assess the recordings.

The choice of the various conditions under which the recordings were to be made posed the first problem. It was clear that it would be dangerous to answer the question 'What is the greatest permissible bass rise?' for one set of conditions only; the answer might depend on such factors as the type of microphone, the microphone-to-speaker distance, the type of voice or even the nature of the passage being read. Furthermore, because the assessments were subjective it was not easy to find valid grounds for *a priori* rejection of any factor or the effect of interactions between factors. It soon became clear that to investigate the problem exhaustively would be very time consuming and expensive; it might cost as much as the savings likely to accrue from a reduction in the demand for bass absorbers.

It was therefore decided to concentrate on what were thought likely to be the main factors. To establish the scope of the investigation a preliminary experiment was carried out first.

3. PRELIMINARY ASSESSMENTS

Recordings of male speech were made in the experimental studio after adjusting the reverberation-time/frequency characteristic to be as uniform as possible. This

* So far, at least, the derivation of reverberation-time formulae has required either the wavelength to be small compared with the linear dimensions of the room, or the room to have a homogeneous distribution of energy and intensity,[2] which is difficult and perhaps impossible to achieve at low frequencies in a small room.

condition is shown as condition K in Fig. 1, (curve (*a*)); the reverberation-time measurements were made at ten microphone positions, using the automatic test-tape method.[3]

Most of the bass absorbers were then removed, and some adjustments made to maintain the reverberation-time reasonably constant above 500 Hz. The curve for this condition (condition O) is shown in Fig. 1 (curve (*b*)). Recordings of male speech were made for condition O, positioning the microphone and speaker as for condition K.

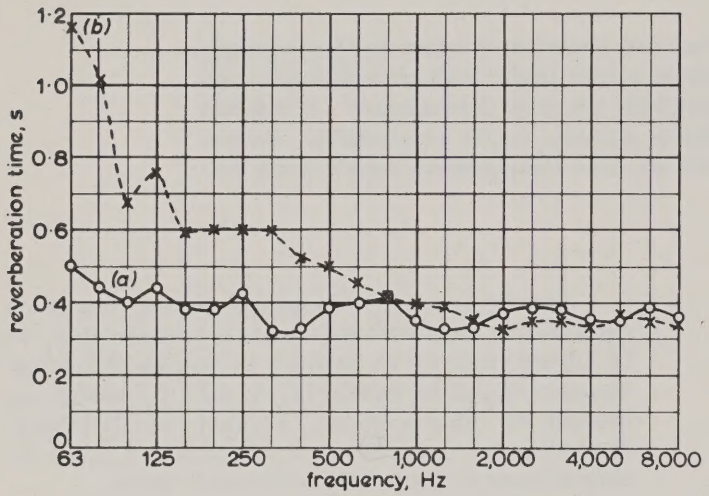

Fig. 1 - Experimental studio. Reverberation-time/frequency curves for preliminary assessments

(*a*) o———o Condition K
(*b*) x- - - - - - x Condition O

For both conditions, four voices, two types of microphone and two microphone-speaker distances were used, resulting in 32 recordings which were played back in a listening room and assessed by four listeners, using the impairment grading scale of Table 1.

TABLE 1

Impairment	Grade
Imperceptible	1
Just perceptible	2
Definitely perceptible but not disturbing	3
Somewhat objectionable	4
Definitely objectionable	5
Unusable	6

The mean grade of all the recordings involving condition K was 2·2, and for all those involving condition O was 3·9. The greatest variation in grading was associated with the change in room condition. The changes of voice and the individual listener preferences appeared to have least effect on the grading.

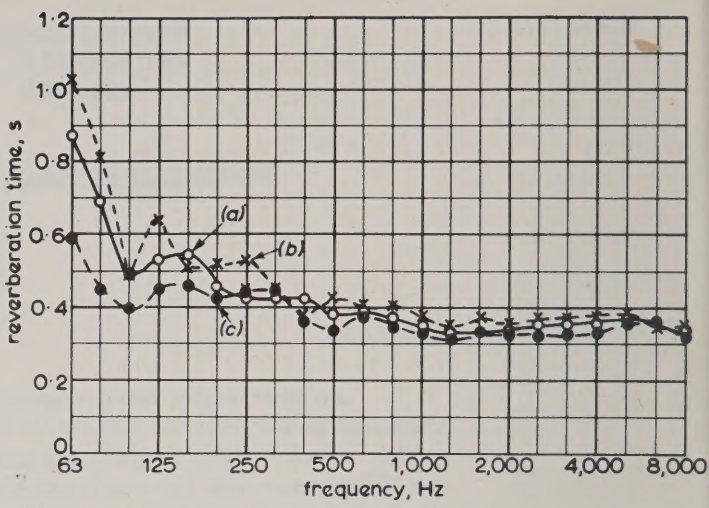

Fig. 2 - Experimental studio. Reverberation-time/frequency curves for intermediate conditions

(*a*) o———o Condition Q
(*b*) x- - - - - - x Condition R
(*c*) ●- - - - - - ● Condition S

4. MAIN ASSESSMENTS

In the light of the results of the preliminary assessments, further recordings were made with three intermediate reverberation-time/frequency conditions, Q, R and S shown in Fig. 2 (curves (*a*), (*b*) and (*c*), respectively). Table 2 shows the different factors (voice, room condition, etc.) varied for the recordings and the variations made in each of the factors (such as K, O, PGS, Far, etc.).

TABLE 2

Factor	Variations of factor				
Voice	NFS	SAH	KFL	–	–
Room condition	K	O	Q	R	S
Microphone	PGS	C12	–	–	–
Microphone distance	Far	Near	–	–	–
Listener	Specialist	Non-Specialist	–	–	–
Bass-cut	No	Yes	–	–	–

The selection of the factors and their variations will now be considered in more detail in Sections 4.1 to 4.7 inclusive.

4.1. Voice

Three readily-available voices were used. All had taken part in the preliminary assessments. A fourth voice which gave the highest mean grading in the preliminary assessments was dispensed with because it appeared that listeners were least able to distinguish conditions O and K with this voice.

The use of professional announcers would have been more appropriate but it was thought to be impracticable.

4.2. Room Conditions

The three intermediate room conditions were the best that could be arranged within a reasonable time. The failure of reverberation-time formulae at low frequencies made it very difficult to achieve a smooth variation among the three conditions.

4.3. Microphone

A ribbon microphone (PGS) and a cardioid microphone (C12 in the cardioid condition) were used. Figure-of-eight ribbon microphones are used in talks studios especially where two speakers can sit either side of the microphone. A cardioid microphone is used at the centre of a round-table discussion, with its principal axis pointing upwards.

It would have been impracticable to have included all the types of microphones used in the BBC, but these two were considered sufficiently representative.

4.4. Microphone Distance

The distance between the speaker and the microphone was described as 'Far' or 'Near', the distances roughly corresponding to the range at which these microphones are normally used, but tending somewhat towards greater-than-usual distances so as to enhance the effect of the room. Table 3 shows the distances employed.

TABLE 3

Microphone	Far	Near
PGS	0·91 m	0·46 m
C12	0·61 m	0·30 m

In some locations, e.g. continuity studios, microphones are used at much smaller distances, but in such situations the reverberation characteristics of the room are relatively unimportant.

4.5. Listener

Listeners were asked to classify themselves as 'specialist' or 'non-specialist'. The aim here was to see if there were any differences in the assessments of those who had a conscious interest in sound reproduction compared with those who listened to broadcast speech solely for its information content. The instructions to listeners are given in the Appendix.

All the listeners, 22 specialist and 22 non-specialist, were drawn from the staff of Research Department.

4.6. Bass-cut

All the recordings made were copied, adjustment being made to compensate for any differences in level. A further copy of each recording was made after passing through a bass-cut filter designed to compensate for the rising bass characteristic of a pressure-gradient microphone at 0·46 m distance.

4.7. Passages

Four short passages from a book were read by the three speakers, different passages being used so that the results would not depend strongly on peculiarities of any one. It was not thought to be worth-while to separate the effects of passages so they were distributed evenly among the other combinations of factors; thus this factor is not listed in Table 2. Each recording contained only one passage, but each speaker read all the passages an equal number of times.

The passages are given in the Appendix.

4.8. The Listening Test

One hundred and twenty recorded extracts, (3 voices x 5 room conditions x 2 microphones x 2 distances x 2 bass-cut conditions) were played to groups of five or six listeners (each group containing both specialists and non-specialists), and the tests were divided into two sessions of 60 extracts each. Each session lasted about 30 minutes, the most that one could ask a listening panel to tolerate without fatigue.

5. ANALYSIS OF THE OBSERVATIONS

For each extract, mean grades were calculated corresponding to the two types of listener, specialist and non-specialist. The standard deviation of the grades for each extract had an average close to unity for both the specialist and non-specialist groups.

The mean grade for each extract was then used for an examination of the results by analysis of variance techniques; a suitable computer programme* was used to process the data. This produced a list of means, sums of squares and variances for all possible ways of classifying the data in terms of the six factors and the combinations of the factors. The ratios of the variances were then examined and compared with a tabulated F-distribution[4] to detect those factors which were significantly affecting the results.

For those factors which were significant, it was then necessary to establish which variations of the factors were having a significant effect. This was assessed by using Student's t-test for all variations of a factor taken two at a time.[4]

6. THE RESULTS

The results for all the factors and combinations of factors are too numerous to give here. Table 4 shows the significant ones.

* Elliott users applications library programme 803 LS3 'Analysis of Variance'.

It was decided that a confidence level of 5% or better would be regarded as significant for the purposes of this investigation.

TABLE 4

Sources of Variation	Level of Significance
Between voices	1%
Between room conditions	5%
Between microphone types	1%
Between microphone distances	5%
Room condition x microphone type combination	5%

The type of listener and the use of bass-cut had no significant effect on the grading.

6.1. Room Condition

The mean gradings for all the observations classified on the basis of room condition are shown in Table 5.

TABLE 5

Room Condition	R	S	K	Q	O
Mean Grade	2·81	2·83	2·83	3·14	3·46

There was no significant difference within the pairs O,Q; K,S; S,R or K,R even at the 10% level of significance, whereas the differences in the six remaining pairs were significant at the 2·5% level or better.

It is concluded that conditions K,R and S form a class differing significantly from the class formed by conditions O and Q. This result is unexpected, especially as nowhere below 250 Hz is the reverberation time for condition R significantly below that of condition Q. No precise explanation has been found for this result; it can only be assumed that there was some factor affecting the assessments that was ignored or not controlled sufficiently closely.

6.2. Voice

As might have been expected, the differences in the voices used were significant; the overall grading associated with the deepest voice, SAH, was 3·4, contrasting with 2·6 for NFS. Although noteworthy, the strong dependence on voice characteristics cannot have practical significance as it would not be feasible to bar bassy speakers from certain studios.

6.3. Microphone Type

On the whole, the PGS microphone (mean grade 2·8) was preferred to the C12 (mean grade 3·2).

6.4. Microphone Distance

The near microphone distance (mean grade 2·8) was preferred to the far microphone distance (mean grade 3·2).

6.5. Interaction of Room Condition and Microphone Type

Table 6 shows the mean gradings for all the combinations of room conditions and microphone type. The brackets underneath the combinations separate groups which differ significantly at the 10% level or better.

The interaction does not seem to affect the preference for the PGS microphone but it does affect the preferences for room conditions. For example, room condition O is preferred to room condition Q if a PGS microphone is used, but Q is preferred to O if a C12 is used.

7. RECOMMENDATIONS

The scope of the investigations was restricted to the region where assessments would be expected to be around grade 3, (definitely perceptible, but not disturbing). In making recommendations of the permissible bass rise, it would not be appropriate to apply the usual forms of criterion,[5] (e.g. that the bass rise should be such that only 10% of listeners assess the grade to be greater than 3·5). For only nine of the 120 recorded extracts was this criterion satisfied, and none of these nine was read by SAH; without knowing the distribution of the characteristics of speakers' voices in broadcasting it would be unfair to apply this criterion.

A more reasonable criterion may be based on the result that, on the whole, conditions K, R and S were indistinguishable, (Section 6.1). Since we are concerned with the maximum permissible rise, it would, at first sight, seem that the curve for condition R should be the appropriate maximum. However, it might be objected that this curve corresponds to higher reverberation times, at certain frequencies than condition Q, which was judged significantly poorer than condition R. Against this is the argument that condition Q was probably poorer because of some factor other than bass reverberation-time (e.g. greater colouration). To argue otherwise would imply that the bass reverberation-time/grading function does not always

TABLE 6

Room and Microphone	K,PGS	S,C12	R,C12	R,PGS	O,PGS	S,PGS	Q,PGS	Q,C12	K,C12	O,C12
Mean Grade	2·29	2·73	2·79	2·82	2·89	2·94	3·05	3·24	3·38	4·03
Grouping										

have a positive slope, a hypothesis for which there is no support from previous experience. Even if this hypothesis were true, the true nature of the bass reverberation-time/grading function would be very difficult and expensive to establish and would probably result in recommendations too complicated to be useful in practice.

Nevertheless, it would be prudent to err on the side of caution and it is proposed that the recommended maximum permissible bass rise curve should be the mean of conditions Q and S with the minor inflections smoothed out, as in Fig. 3.

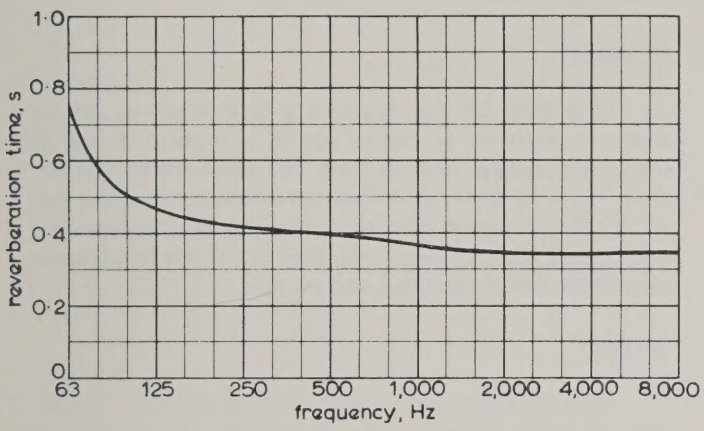

Fig. 3 - Recommended maximum permissible bass rise for talks studios

If future experience indicates that this recommendation is over-cautious, the situation could be reviewed and a further bass rise permitted.

It must be stressed that, for the present, the curve of Fig. 3 is the maximum permissible curve and should not be exceeded. If the designer of a talks studio has only unreliable data on the bass absorbers he proposes to use he may still have to aim for a flat reverberation-time/frequency characteristic. The more immediate value of the curve of Fig. 3 is that it gives an objective criterion which allows talks studios whose characteristics are found to fall below this curve to remain unmodified.

There is no evidence available which shows how the curve of Fig. 3 should be scaled should the high-frequency reverberation time be different from 0·35 seconds, but it is likely that a very low reverberation-time at high frequencies would accentuate the effects of a given bass rise and *vice versa*.

8. CONCLUSIONS

The results of this investigation show that whether or not a given bass rise is acceptable depends on the speaker, the microphone in use, and the distance between the speaker and the microphone.

Nevertheless the results show reasonable grounds for allowing a bass rise and a permissible maximum is suggested.

Neither the two different types of listeners nor the use of bass-cut significantly affected the acceptability of bass rise.

9. REFERENCES

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3. An automatic method for the measurement of reverberation time. BBC Research Department Report No. 1969/23.

4. MOORE, P.G. *and* EDWARDS, D.E. 1965. Standard statistical calculations. London, Pitman, 1965.

5. A simple application to broadcasting of the results of subjective tests. BBC Research Department Report No. A-091, Serial No. 1966/43.

APPENDIX

I. INSTRUCTIONS TO LISTENERS

1. These experiments are an attempt to assess – firstly, – how much bass or low-frequency reverberation we can tolerate in a talks studio; secondly, – whether we can filter out the low-frequencies in a 'bassy' studio without producing any worse effects.

2. In the test you will hear a number of extracts of voices speaking which are separated by short pauses. After hearing each extract, write on the form a number corresponding to your assessment of the grading as indicated on this chart. You may use half-grades if you wish. If you have difficulty in deciding on a standard, imagine yourself to be a radio producer.

3. Your assessment should be based on defects you associate with the acoustics, or lack of acoustics of the studio, or lack of low frequencies. In other words don't be influenced by changes, for example, in loudness, noise level or other factors we haven't been able to control.

4. To help you keep track, the number of the extract will be displayed here.

5. Write any comments you have at the bottom of the form.

6. Please write your name at the top of the form and classify yourself as either a 'specialist' or a 'non-specialist' listener; a specialist if you have a professional interest or you are interested in good sound reproduction for its own sake, otherwise classify yourself as a non-specialist.

7. There are 120 extracts in all. We are proposing to break the test into 2 sessions of 60 extracts. However, after 30 extracts we will give you a short break. The 60 extracts take about 25 minutes.

8. Firstly I will play 3 extracts as an example.

9. Any questions?

II. THE PASSAGES READ

The passages were taken from the 1958 impression of 'The Complete Plain Words' by Sir Ernest Gowers (published by HMSO). Passages 1 and 2 are on page 5 and are from an article by George Orwell in the April 1947 'Horizon'. Passages 3 and 4 are on page 67 and were written by Dr. P.B. Ballard in 'Teaching and Testing English' (University of London Press, 1939).

Passage 1

A scrupulous writer in every sentence that he writes will ask himself .....What am I trying to say? What words will express it? .....And he probably asks himself ..... Could I put it more shortly? But you are not obliged to go to all this trouble.

Passage 2

You can shirk it by simply throwing open your mind and letting the ready-made phrases come crowding in. They will construct your sentences for you – even think your thoughts for you to a certain extent – and at need they will perform the important service of partially concealing your meaning even from yourself.

Passage 3

The word 'as' has acquired a wide vogue in official circles. Wherever 'as' can be put in, in it goes. A man in the public service used to draw his salary from a certain date; now he draws it as from a certain date. Time was when officials would refer to 'the relationship between one department and another'; now they call it 'the relationship as between one department and another'.

Passage 4

Agenda papers too often include as an item: 'to consider as to the question of'. If this sort of interpolation between the verb and its object were extended to ordinary speech, a man would no longer 'eat his dinner' but 'eat as to his dinner'; or, to make the parallel complete, 'eat as to the diet of his dinner'.

The authors of this report wish to thank A.M. Heath and Co. Ltd. for permission to reproduce the extract by George Orwell, and University of London Press Ltd., for permission to reproduce the extract by Dr. P.B. Ballard.

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